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TRANSFORMATION OF THE DISCRIMINATIVE AND ELICITING FUNCTIONS OF GENERALIZED RELATIONAL STIMULI

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In three experiments, match-to-sample procedures were used with undergraduates to establish arbitrary relational functions for three abstract visual stimuli. In the presence of samples A, B, and C, participants were trained to select the smallest, middle, and largest member, respectively, of a series of three-comparison arrays. In Experiment 1, the B (choose middle) stimulus was then used to train a steady rate of keyboard pressing before the A (choose smallest) and the C (choose largest) stimuli were presented. Participants pressed slower to A and faster to C than to B. Then B was paired with mild shock in a Pavlovian procedure with skin conductance change as the dependent variable. When presented with A and C, 6 of 8 experimental participants showed smaller skin conductance changes to A and larger skin conductance changes to C than to B. In Experiment 2, A was then used as a sample in a match-to-sample procedure to establish an arbitrary size ranking among four same-sized colored circle comparisons. One of the middle circles was then used to establish a steady rate of pressing before the other circles were presented. Five of 6 participants responded slower to the ''smaller'' circle and faster to the ''larger'' circle than they did to the ''middle'' circle. In Experiment 3, A, B, and C were then presented on a series of test trials requiring participants to pick the comparison that was less than, greater than, or equal to the sample. Novel stimuli were included on some trials. Results indicated that the relational training procedures produced derived relations among the stimuli used in training and that these allowed correct inferences of relative size ranking among novel stimuli.

Key words: transfer, transformation of functions, relational stimuli, relational responding, derived relations, classical conditioning, skin conductance, keyboard pressing, humans

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The transfer or transformation of functions among the elements of stimulus equivalence classes is a robust phenomenon. By transformation of function, we are referring to the indirect acquisition of stimulus functions that occurs after an equivalence class or set of stimulus relations is established and a novel function is subsequently trained for selected elements of that class or relation (see Dougher & Markham, 1996; Dymond & Rehfeldt, 2000; Hayes, 1991; Hayes & Barnes, 1997; and Sidman, 1994, for further discussion). For example, after establishing two 4-member equivalence classes using match-to-sample procedures, Dougher, Augustson, Markham, Greenway, and Wulfert (1994) then selected one member of one of the classes and used it as a conditional stimulus (CS) in a Pavlovian conditioning procedure, with shock as the unconditioned stimulus and skin conductance as conditioned and unconditioned responses. Subsequent tests revealed that all the members of the class from which the CS had been selected had indirectly acquired fear-eliciting functions, but none of the members of the other class did.

Using roughly similar procedures, investigators have reported the transfer or transformation of virtually every stimulus function, including simple discriminative control (de Rose, McIlvane, Dube, Galpin, & Stoddard, 1988; Roche, Barnes-Holmes, Smeets, Barnes-Holmes & McGeady, 2000), self-discriminative control (Dymond & Barnes, 1994, 1995), conditional stimulus control (Roche & Barnes, 1996; Wulfert & Hayes, 1988); contextual control (Gatch & Osborne, 1989; Hayes, Kohlenberg, & Hayes, 1991), ordinal functions (Green, Sigurdardottir, & Saunders, 1991; Lazar, 1977; Lazar & Kotlarchyk, 1986; Wulfert & Hayes, 1988), conditional reinforcement and punishment (Greenway, Dougher, & Wulfert, 1996; Hayes et al., 1991), avoidance evocation (Augustson & Dougher, 1977), respondent elicitation (Dougher et al., 1994; Roche & Barnes, 1997; Roche et al., 2000), and extinction of respondent elicitation (Dougher et al., 1994).

Thus far, we have used the terms transfer and transformation interchangeably, but there are differences in how the terms are used in

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the literature. Transfer of function tends to be used when untrained function acquisition is based on stimulus equivalence and the trained and resulting untrained functions are the same (Dymond & Rehfeldt, 2000; but see Sidman's, 1994, objection to the use of the term transfer and his preference for describing this phenomenon as the union of stimulus classes). Transformation of function tends to be used when untrained function acquisition is based on stimulus relations other than equivalence (e.g., opposition, greater than, less than), and the trained and resulting untrained functions are different (Dymond & Barnes, 1995; Roche et al., 2000). For example, if stimulus A and B are in a relation of opposition, and A is then given a fear eliciting function, then fear elicitation likely will not transfer to B. However, the relation of opposition between A and B could transform the behavioral functions of B so that it becomes a safety signal or even a reinforcer. Because the present paper is concerned with comparative relations (smallest, largest) rather than equivalence relations, we use the term transformation.

Two studies have investigated the transformation of functions based on stimulus relations similar to those investigated in the present study. The first, Dymond and Barnes (1995), examined the transformation of self-discrimination functions based on the relations sameness, more than, and less than. Using match-to-sample (MTS) procedures, a relational function was trained for three contextual cues. In the presence of the SAME contextual cue, selections of comparisons that matched the sample were reinforced. In the presence of the LESS-THAN and the MORE-THAN cues, selections of comparisons that were either less than or more than the sample, respectively, were reinforced. For example, in the presence of the LESS-THAN cue, selections of a two-star comparison in the presence of a three-star sample were reinforced whereas in the presence of the MORE-THAN cue, selections of a six-star comparison in the presence of a three-star sample were reinforced. After this relational pretraining, six arbitrary relations were trained using the three contextual cues. The four critical relations were: SAME/A1–B1 (in the presence of the SAME cue and sample A1, select comparison B1 rather than B2, thus, A1 is the same as B1); SAME/A1–C1; LESS THAN/A1–B2 (in the presence of the LESS THAN cue and sample A1, select comparison B2, thus, B2<A1); and MORE THAN/A1–C2 (in the presence of the MORE THAN cue and sample A1, select comparison C2, thus, C2>A1). Seven derived relations then were tested, the most important being: SAME/B1–C1, MORE THAN/B1–C2, and LESS THAN/B1–B2. Correct responding on these trials indicated that the participants were responding in line with the derived relations of sameness, more than, and less than.

Participants were then exposed to a three-stage self-discrimination-training task, each stage of which involved a schedule-control task and a matching-to-sample task. In the first stage of training of the schedule-control task, participants were exposed to a three-component mixed reinforcement schedule intended to produce 0, 1, or 2 presses on the space bar of a computer keyboard. If the participants did not press the space bar (0 presses), a novel stimulus, X1, was presented on a computer screen. If they pressed the bar once, the stimulus B1 was presented, and if they pressed the bar twice, a novel stimulus, X2, was presented. In the subsequent match-to-sample task, the sample was the same stimulus that was on the screen at the end of the schedule control task, the comparisons were X1, B1, and X2, and selecting the comparison that matched the sample was reinforced. The second stage was identical to the first except that no sample was presented during the match-to-sample task. Comparison selections had to be made on the basis of the stimulus present on the screen at the end of the previous schedule-control task or the number of responses subjects made on that trial. The third stage was identical to the second except that no stimulus was presented after subjects made a response. Comparison selections had to be made solely on the basis of the number of responses the participants made on the previous trial. In this way, participants had to discriminate their own behavior on the schedule-control task in order to respond correctly on the subsequent match-to-sample task. Thus, selections of X1 were considered correct if subjects made no responses on the last trial, selections of B1 were correct if they made one response, and selections of X2 were correct if they made two responses.

The final phase of the experiment entailed two self-discrimination tests. The first was identical to the last self-discrimination-training task except, C1, B2, and C2 served as the comparisons on the match-to-sample task. Responding correctly indicated that these stimuli had, via derived relating, acquired the functions of B1, X1, and X2, respectively. The second test involved a reversal of the order of the tasks in Test 1. Participants were first presented with the C1, B2, or C2 stimulus and then required to select from the comparisons B1, X1, and X2 the stimulus that corresponded to what they ''intended to do'' on the following schedule task. They then were presented with the schedule task, and their responses were recorded. In the end, participants demonstrated the transformation of self-discrimination response functions in line with the derived relations of sameness, more than, and less than.

The second study, Roche et al. (2000), reported contextual control over the transformation of both simple discriminative and respondent-eliciting functions. Of particular interest here was the transformation of the eliciting functions. Using adult participants, these researchers established the contextual functions of SAME (S) and OPPOSITE (O) for two arbitrary stimuli, trained the relations S/A1–B1, S/A1–C1, O/A1–B2, and O/A1–C2, and then tested for the derived relations S/B1–C1, S/B2–C2, O/B1–C2, and O/B2–C1. Following this, B1 and B2 were paired in a respondent-conditioning paradigm with videotaped presentations of sexual and nonsexual material, respectively, to establish a conditional skin response to B1. Finally, four probes, S/C1, S/C2, O/C1, and O/C2 were presented to test for the contextual control of the transformation of functions. The results, which were presented as group data, indicated that subjects showed greater conditional arousal to both the S/C1 and O/C2 probes than either of the S/C2 or O/C1 probes.

Although both of these studies make important contributions to the literature on stimulus relations and the transformation of stimulus functions, their procedures allow for some ambiguity in how the results are interpreted. With respect to the Roche et al. (2000) study, it could be argued that the relational training resulted in a set of contextually controlled pairs of functionally equivalent stimuli (Sidman, 2000). For example, in the presence of contextual cue S, A1–B1, A1–C1, B1–C1, and B2–C2 became equivalent pairs, whereas in the presence of contextual cue O, A1–B2, A1–C2, B1–C2, and B2–C1 became equivalent. The relational testing trials themselves may have facilitated this outcome. Thus, the transformation of functions that occurred could be said to have been equivalence based.

With respect to the Dymond and Barnes study (1995), subjects' performances on the relational testing trials clearly seem to be controlled by the derived relations, same, more than, and less than. Moreover, the ease with which B2 and C2 acquired the functions of X1 and X2, respectively, argues strongly that the respective stimuli meant the same thing or shared the same relational functions. That is, both B2 and X1 meant less than, and both C2 and X2 meant more than. However, it is precisely because of this already existing shared function that one could argue that B2 and C2 acquired their self-discrimination response functions on the basis of functional equivalence. Because B1 and C1 both had been directly paired with X1, the transformation of C1's self-discrimination function could have been equivalence based rather than based on the relation less than, as assumed.

The fact that the transformation of self-discrimination functions in this study may have been equivalence-based in no way diminishes the importance of the findings or undermines the authors' contention that stimulus functions can be acquired via derived stimulus relations other than equivalence. It does, however, suggest that the transformation of functions other than those that were used to train and test derived relational responding has not yet been unambiguously demonstrated.

As stated earlier, in equivalence-based transfer of function, the functions that transfer are usually the same as those that have been directly trained for one or more members of the existing equivalence class. A particularly interesting implication of function transformation based on relations other than equivalence is that the functions that are indirectly acquired by related stimuli could be quite novel, depending on their relation to the directly trained stimuli. For example, if relational training procedures can establish a more than–less than relationship among three stimuli, such that A<B<C, and a function is then trained for B, then A and C may occasion different responses than those occasioned by B. More specifically, if after the relationships A<B<C have been established, and B is then made discriminative for a certain rate of bar pressing, it is possible that A would occasion a lower rate of responding than B, and C would occasion a higher rate of responding than B. Similarly, if B were used as a conditional stimulus (CS) in a respondent fear-conditioning paradigm, A might elicit a smaller fear response and C might elicit a larger fear response than that elicited by B.

Such findings would have theoretical and applied significance. First, they would demonstrate the transformation of functions via stimulus relations other than equivalence. Second, they would begin to offer a behavior-analytic account of complex behaviors like interpretation and extrapolation. Third, they would provide a behavioral alternative to cognitively based explanations of differential fear reactions to stimuli that have never been directly associated with aversive stimulation.

EXPERIMENT 1

Method

Participants

Participants were 21 (12 experimental, 7 females and 5 males, and 9 control, 5 females and 4 males) undergraduates (age range = 19–27) in introductory psychology courses recruited through in-class and bulletin board announcements. All received course credit for their participation. At the beginning of this and the following two experiments all participants read and signed statements of informed consent that emphasized that they could discontinue participation at any time during the experiment. Upon completion of the study, all participants were fully debriefed. The Human Research Review Committee at the University of New Mexico reviewed and approved all of the procedures for the present experiments

Setting, Apparatus, and Stimuli

The experiment room was 3 m by 3 m and equipped with a table, chair, two-way mirror for participant observation, and a personal computer with a standard keyboard and 15 in. color monitor. The computer was programmed to present all stimuli and record participants' responses. Stimuli were black shapes and forms presented on a white background.

A physiological response recording system (Model # I-330 C2; J&J Engineering, Pouslbo, WA) was used to measure and record skin conductance. The system included silver chloride electrodes, which were attached with Signa Creme (Parker Laboratories, Fairfield, NJ) to the palmar side of middle finger of the nondominant hand between the first and second knuckle. A square wave stimulator (Model 82415 IS, Lafayette Instrument Co., Lafayette, IN) was used to deliver shock. Shock electrodes consisted of two 6.25 mm nickel-plated electrodes fastened 6.25 mm apart to a 35 mm wide x 50 mm long piece of Plexiglas. The Plexiglas was strapped to participants' dominant forearm with a Velcro strip. Participants' forearms were prepared with Ten20 conductive paste (D. O. Weaver and Co., Aurora, CO).

Procedure

Experiment 1 consisted of four phases for the experimental participants and three phases, as described below, for the control participants. All phases were conducted in one session that lasted between 90 and 120 min. Participants were run individually.

Phase 1: Participant screening and shock selection. Participants reported to the laboratory and were greeted by two experimenters, who had been thoroughly trained in the experimental procedures. In a room adjacent to the experiment room, one of the experimenters explained the general procedures to the participants and had them sign a statement of informed consent. Participants then were taken to the experiment room, seated in the chair facing the computer monitor and keyboard, and had the skin conductance and shock electrodes attached as previously described.

To ascertain that participants were ''skin conductance responders,'' they were administered a balloon-burst test, a commonly used procedure in studies using skin conductance measures (Levis & Smith, 1987). The test began with a 2-min baseline, during which participants were asked to sit quietly and refrain from moving while their skin conductance levels were recorded. Following this, participants were blindfolded and asked to inflate a balloon. When the balloon was inflated almost to the point of bursting, the experimenter pricked it with a pin causing it to pop. Participants were defined as skin conductance responders if they showed a skin conductance response of at least 2 micromhos (microsiemens) during the ensuing 15-s interval. Three participants failed to meet this criterion and were excused from the study. Nine participants (5 females and 4 males) met criterion and moved on to the shock-selection procedures.

Participants were told that the purpose of this stage of the study was to select an ''uncomfortable but not painful'' shock level to be used later in the experiment. The shock generator was set to level 7 (levels ranged from 1–10), and a brief (50 ms) shock was administered. Participants were asked to rate the aversiveness of the shock on a scale of 1–10, with a rating of 8 indicating that the shock was uncomfortable but not painful. If participants rated the initial shock as anything other than an 8, the shock level was increased or decreased and another shock was administered. This procedure was repeated until participants rated the shock an 8. A second shock at that level was administered to determine whether the participants' ratings remained stable. This procedure was repeated until participants rated a given shock level an 8 on two consecutive administrations. Of the 9 participants who went through this procedure, one male was excluded because he rated all shock levels below an 8. This left a total of 8 participants (5 females, 3 males) for the next phase of the study. Because the shock generator used in the study allowed only for the adjustment of voltage, the actual current administered to participants varied as a function of their skin resistance, which was unknown. What was constant across participants was a shock level that was rated as uncomfortable but not painful.

Phase 2: Relational Training. To begin this phase, participants were orally presented the following instructions:

> A symbol will appear on the computer at the top of the screen accompanied by three more symbols along the bottom: one in the lower left, one in the lower middle, and one in the lower right. Your job will be to select the correct symbol at the bottom of the screen given the one at the top. There is always one and only one correct answer. You will make your selections by pressing one of the arrow keys. Press the left arrow key to select the symbol on the left, the down arrow key to select the symbol in the middle, and the right arrow key to select the symbol on the right. When your selection is correct, the word 'correct' will appear on the screen. When your selection is incorrect, the word 'wrong' will appear on the screen. Later, you will receive some trials where you will get no feedback, but there will still be a correct answer. Use what you learn on the trials with feedback to make your selections on the trials with no feedback. You must complete the feedback trials with at least 95% accuracy to go on to the trials with no feedback. Please pay close attention and try not to make any mistakes. You cannot change a selection once it has been made. Your performance on this task will determine how long the task lasts, so do your best to make correct selections. Do you have any questions? (If no questions), Please begin.

Once the participants indicated that they understood the instructions, they began the relational training tasks, which used an arbitrary match-to-sample procedure to establish relational discriminative functions for three nonsense visual samples. At the beginning of every trial, one of three sample stimuli, A, B, or C, was presented in the horizontal center of the top third of the computer screen. Along with the sample, three comparison stimuli were presented equidistant from each other across the lower third of the screen with the middle comparison located in the horizontal center. On all trials, the three comparisons were identical in form but varied in size. Across trials, the comparisons varied in form, as described below.

The purpose of the task was to train participants to select the smallest comparison in the presence of sample A, the middle comparison in the presence of sample B, and the largest comparison in the presence of sample C. In the early part of this training phase, experimentally defined correct selections cleared the screen and produced the written feedback ''Correct.'' Incorrect comparisons produced the written feedback ''Wrong.'' The feedback remained on the screen for 2 s, and an intertrial interval (ITI) of 1 s preceded the next trial.

Across trials, comparison arrays varied along two dimensions: the absolute size of the

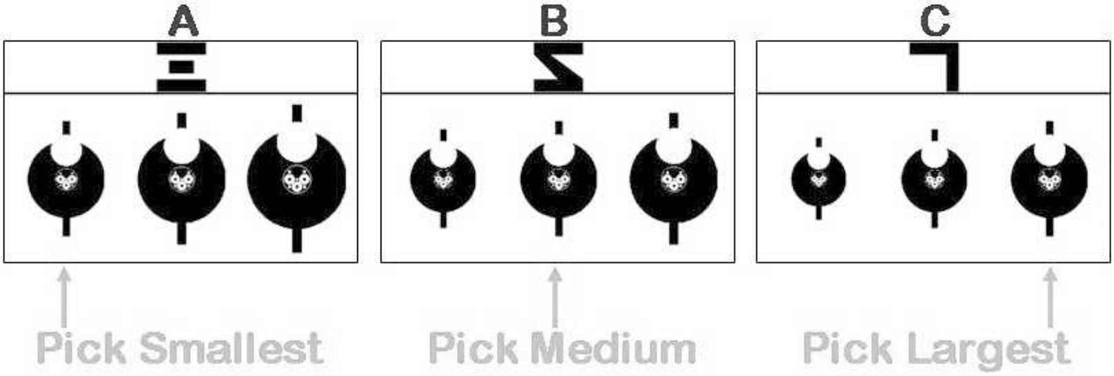

Fig. 1. Three examples of trials used in the relational training task.

individual comparisons and their visual form. As mentioned before, on any given trial the visual form of the three comparisons was identical, but they varied in size. The visual form of the comparisons remained constant over a series of trials that consisted of some number of quasirandom (see below) presentations of each sample and an appropriate comparison array. A particular sample-comparison array was repeated (although the location of the comparisons varied randomly) until participants made the correct selection, after which, a different sample-comparison array was presented. On subsequent trials within a series, the absolute size of the incorrect comparisons varied depending upon the sample so that the correct comparison across trials varied in relative size but was always the same absolute size. For example, the correct comparison in the presence of sample A was the smallest of the comparisons presented on that trial, but was the same absolute size as the correct comparisons on trials with the B and C samples. In addition, the size of the incorrect comparisons varied across trials with the same samples so that specific comparison arrays were not systematically related to each of the samples. Regardless of whether participants responded correctly or incorrectly on the preceding trial, the location of the different-sized comparisons within an array varied randomly across trials. A typical training trial with each of the sample stimuli is presented in Figure 1.

Participants were required to select the correct comparison in the presence of each sample six consecutive times (18 consecutive trials) within a series before a new series of trials was introduced. The visual form of the comparisons changed with each new series, but the procedures were otherwise the same. The specific form of the comparisons presented on each new series of trials was randomly selected by the computer from a pool of 50 forms created for these experiments. Changing the visual form of the comparisons across series of trials was a form of multiple exemplar training (i.e., successive discrimination training across different sets of stimuli that share a common feature) that was intended to produce generalized conditional control by the sample stimuli over a range of different comparison arrays. Participants were presented with 12 different series of trials consisting of novel comparisons. If they performed at 100% accuracy on all 18 trials of the final (12^{th}) series, three test series with novel comparisons (54 trials) were presented without feedback. Participants were required to perform at 96% accuracy or better on these test trials, before moving to the next phase. If they did not meet this criterion, they received eight additional training series and three additional test series with previously presented stimuli and with the same performance criteria.

Phase 3: Bar press training with the B stimulus and testing with the A and C stimuli. In this phase of the experiment, participants were instructed and trained to push the space bar on the computer keyboard at a steady rate in the presence of the B (medium) stimulus. To start, participants were given the following instructions:

> During this part of the experiment, a symbol will appear in the center of the computer

> screen. The symbol will be one of those you saw in the last part of the experiment. When you see the symbol, your job will be to repeatedly press the space bar on the keyboard the whole time the symbol is presented. You can set your own rate, but we want it to be steady as long as the symbol is present. You will be able to see how fast you are pressing because a mark will appear on the screen each time you press the bar. You will not receive any feedback because there are no right or wrong responses. At first, the same symbol will be presented repeatedly. Once you are able to press the bar at a steady rate to that symbol, a different symbol will be presented. Press the bar at a rate that you think is appropriate for each symbol you see. Do you have any questions?

Once participants indicated that they understood the instructions, the experimenter activated the program, which presented the B stimulus in the center of the screen, and then demonstrated how to press the bar at a steady rate. Each bar press produced a dash along the bottom of the screen, which could be used to assess the number or rate of bar presses. The experimenter pressed the space bar about once per second for the 30 s duration the B stimulus remained on the screen. A second trial was initiated, and the participant was asked to press the bar at a rate that felt comfortable and that could be maintained as long as the stimulus was present. Trials were repeated until participants were able to maintain a constant rate (within + or − 10% of the number of presses on the previous trial) for three consecutive trials, which all participants reached within four training trials. Following this, the testing phase of the program was activated, and the computer presented the following sequence of stimuli: B B B B A B C. Each stimulus was presented for 30 s, and there was a 1-s ITI that preceded the onset of the next stimulus. Participants' bar presses to each of the stimuli were recorded on the computer.

Phase 4: Respondent conditioning with the B stimulus and testing with the A and C stimuli. Upon completion of the bar press task, participants began the respondent conditioning phase of the study. During this phase, the B stimulus served as the CS, shock as the US, and skin conductance change (in micromhos) as the dependent variable.

At the start of this phase, the following instructions were orally presented:

> This part of the experiment will be like the last in that one of the symbols you have seen before will be presented in the center of the computer screen. However, during this part of the experiment, you will also receive some electric shocks, and we will record your skin responses. Before beginning this part of the experiment, we will ask you to sit quietly for a few minutes. During this time, the computer screen will be blank. After that, you will see a small cross on the screen a few seconds before one of the symbols will appear. You don't need to do anything except watch the screen and attend to the symbols. It is very important that you don't let your attention wander from the screen. It is also important that you remain as still as possible, since movements will interfere with our measurements. This part of the experiment will last about 18 minutes. Again, all you have to do is watch the screen and remember to stay as still as possible. No response is necessary. Since the presentations of the stimulus will be separated by relatively long periods where the screen is blank, make sure you continue to pay attention to the screen. Do you have any questions?

After the instructions were presented, participants were asked to sit quietly for 5 min while baseline skin conductance data were recorded. Conditioning trials immediately followed this baseline period. A delayed conditioning procedure was used wherein the B stimulus appeared in the middle of the screen for a duration of 30 s and coterminated with a 50 ms shock at the level previously selected by each participant. Based on previous research (e.g., Dougher et al., 1994), participants received six conditioning trials. Each trial was separated by a 90-s ITI to allow participants' skin conductance levels to stabilize. Ninety s after the last B-stimulus conditioning trial, one A-stimulus trial was presented. This trial was identical to the previous trials except that the A stimulus was presented and the voltage was reduced to half of that presented on the B-stimulus trials. This was intended to prevent the possible partitioning of the three stimuli into two classes: one that was followed by shock (B), and one that wasn't (A and, perhaps, C). In other words, we wanted to prevent participants from concluding that only the B stimulus would be followed by shock. Inasmuch as skin conductance responses to the A stimulus were recorded before the shock was delivered, they could not have been affected by the reduced shock intensity. After a 90-s ITI, one C-stimulus trial was presented with no shock. Again only one C stimulus trial was presented because responding to a stimulus that has no history of association with shock and is not followed by shock typically extinguishes quickly.

Control Participants. In order to determine the relative effects of the relational training on participants' responses during the bar press and respondent test phases, 9 additional participants were exposed to Phases 1, 3, and 4, but not Phase 2, the relational training. All of the control participants were run after the 8 experimental participants completed the study. One male control participant was excluded for failing to meet criterion on the balloon burst test, and 1 male was excluded for rating all of the shock intensities less than 8, leaving a total of 7 (5 females and 2 males) control participants who completed the study.

Results and Discussion

Although there was considerable variability across experimental participants in terms of how quickly they mastered the relational task, all but one met the testing criterion after 12 series of training trials. One participant required eight additional series of training trials, but met the testing criterion after that. It was apparent from observing the participants that a number of them were operating idiosyncratically at first, and it often took a large number of repeated trials in the first few series for the contingencies to take effect. In the end, however, all 8 experimental participants met criterion, and all were able to describe accurately the contingencies that were in effect. Because these data are not critical to the experiment, we present no further detail.

Presented in Figure 2 are the experimental (upper panel) and control (lower panel) participants' bar press rates to the last three stimulus presentations (A, B, and C) in Phase 3. Although there was some variation in rate across participants to all of the stimuli, all 8 experimental participants pressed the space bar more slowly to A than to B, and more slowly to B than to C (A < B< C). This pattern of responding was evident for only 2 (1-C2 and 1-C4) of the 7 control participants. Each of the other 5 control participants produced a different pattern of responding. In all, the 7 control participants produced six different response patterns.

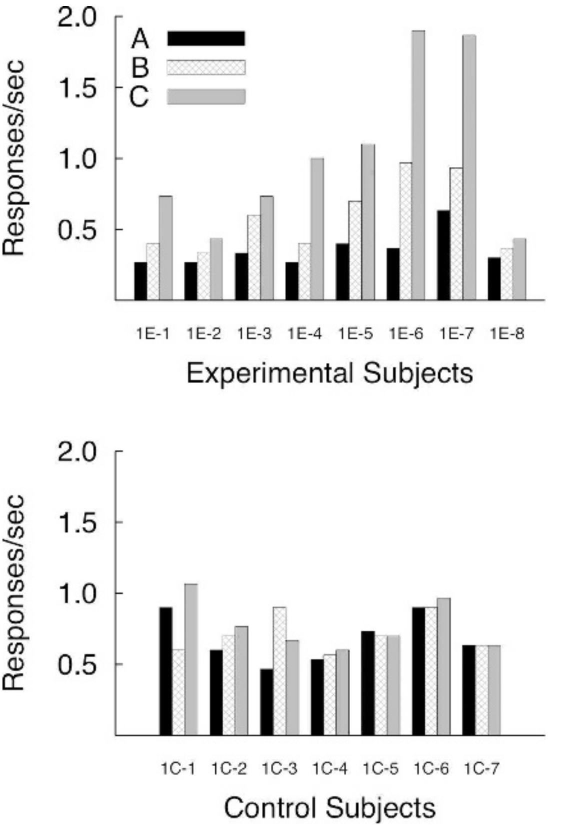

Fig. 2. Responses per second to A, B, and C for the experimental (E, upper panel) and control (C, lower panel) participants in the bar press testing phase of Experiment 1.

Skin conductance change scores for both the experimental and control participants obtained on the last B trial and the A and C trials in Phase 4 are presented in Figure 3. Skin conductance change scores for each stimulus were obtained by subtracting the lowest skin conductance level during the 30 s interval immediately preceding the onset of the presentation of that stimulus from the highest skin conductance level obtained during the 30-s interval following the presentation of that stimulus. In this way, skin conductance levels produced by the A and C stimuli were related to their most proximate baseline levels. Because it took a few trials to establish conditioning with the B stimulus, skin conductance change scores are reported only for the final conditioning trial. As Figure 3 indicates, 6 (1-E1, 1-E2, 1-E4, 1-E6, 1-E7 and 1-E8) of the 8 experimental participants showed patterns of skin conductance changes in line

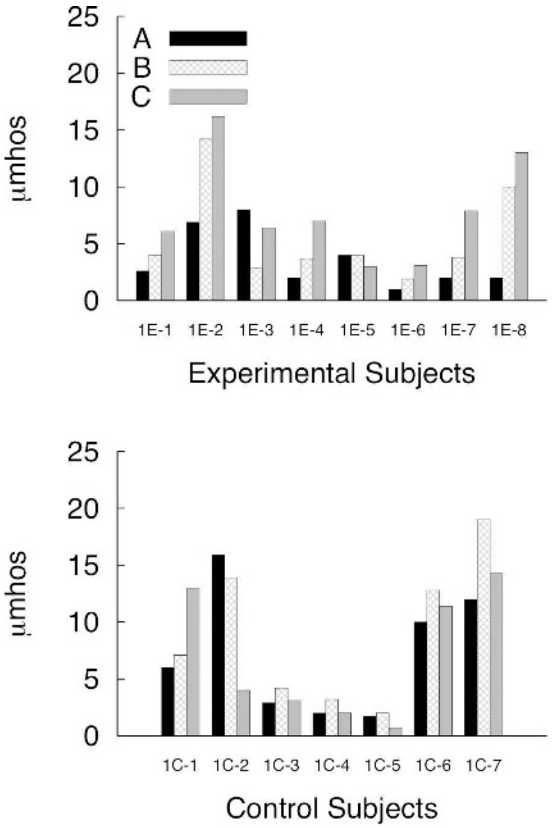

Fig. 3. Skin conductance changes in microsiemens to A, B, and C for the experimental (upper panel) and control (lower panel) participants in the respondent conditioning test phase of Experiment 1.

with their patterns of bar pressing, that is, A < B < C. In contrast, only 1 (1-C1) of the control participants showed this pattern of results. Five of the other 6 control participants showed higher skin conductance changes to B than to either A or C (A < B > C), as would be expected given that B was the only stimulus to be paired with shock, and these subjects did not receive relational training. One control participant (1-C2) deviated from this pattern and showed greater skin conductance change to A than to B, and greater change to B than to C (A > B > C).

Taken together, these results suggest that the relational training determined the relative operant rates evoked by A and C as well as their relative levels of respondent elicitation. Perhaps the most interesting and clinically relevant finding was that, despite never having been associated with shock, C elicited greater skin conductance changes in most experimental participants than B, which was directly paired with shock. It is worth mentioning that the experimenters noted that some of the experimental participants became mildly alarmed when the C stimulus was presented, and at least one tried to remove the shock electrodes from her arm. In addition, although not asked directly, several experimental participants spontaneously reported during the debriefing that they believed they would receive a greater shock to C than they did to B. None of the control participants did so.

The present procedures appear to have eliminated the potential confounds associated with other studies that have purported to show the transformation of functions via relations other than equivalence. Each of the sample stimuli used in the relational training was related equally often to each of the comparisons, which would have precluded the formation of equivalence classes composed of any subset of the samples and comparisons. Moreover, subsequent operant and respondent functions acquired by the samples appear to have resulted from their participation in the relational training procedures. Therefore, the present results support the assertion that the untrained acquisition (transformation) of stimulus functions can result from trained relations other than equivalence and is not dependent upon the formation of stimulus classes.

There are at least two potential limitations of this study. One is that participants were not randomly assigned to the experimental and control conditions. Differences in responding between the two conditions, therefore, may have been at least partly due to participant variables rather than or in addition to the identified independent variable (i.e., the relational training procedures). The control participants were selected 2 to 3 weeks after the experimental participants, but both groups were selected from the same participant pool, and there were no differences in the recruitment procedures used between the groups that would allow participants to knowingly select themselves into either condition. Moreover, there were no obvious differences in age, gender, or ethnicity between the two groups. So, while it is possible that the lack of random assignment may have affected the results, it is not an obvious threat to internal validity.

A second potential limitation is that both the bar-press and respondent test conditions involved only a single probe trial with each of the A and C stimuli, and the order of the probe trials was constant across participants. Our previous experience with respondent procedures has shown that participants quickly learn the relationship between probe stimuli and the delivery of the US. Therefore, a single presentation of A followed by reduced shock or C with no shock would itself likely alter skin conductance responses to those stimuli on subsequent trials. For this reason, we decided to use single probe trials with each stimulus.

With respect to the fixed order of the probe trials, we were operating under two constraints. First, our previous experience with the respondent procedures has shown that shock intensities rated as at least uncomfortable are needed to produce reliable changes in skin conductance, and that was the intensity used with B. Second, the Institutional Review Board would not allow the delivery of shock intensities that were rated higher than uncomfortable but not painful, so we were unable to deliver higher shock intensities following C than B. Those constraints left us with two options: Either alternate the order of A and C and present the same shock intensities following C as followed B, or always present C last. Again because shock intensities on initial probe trials often affect skin conductance responses on subsequent trials, we were concerned that presentations of C followed by the same shock intensity as that which followed B would affect participants' subsequent responses to A. For that reason, we chose always to present C last. The bar press probes were another story. Because no consequences were presented on these trials, multiple probes and multiple orders could have been used. Because they were not, our results speak only to participants' responses on single probes presented in a particular order. Stability of responding over repeated trials was not assessed.

With regard to the samples in the relational training procedures, it seems clear that in general terms they functioned as conditional discriminative stimuli (Sidman, 1994, 2000). That is, they determined which of the comparisons were discriminative for reinforcement (occasioned a selection response) on a particular trial. However, the kind of control exerted by the present samples is different from that exerted by sample stimuli in more typical conditional discrimination arrangements, because the present samples determined the relational rather than the absolute dimensions of the comparisons that were discriminative for reinforcement. For this reason, we are inclined to call the samples relational stimuli. Moreover, we are inclined to call them generalized relational stimuli because their relational functions extend to novel sets of comparisons.

Nonarbitrary relational responding or responding to the nonarbitrary, physical relations among stimuli is not new and has been reported in a variety of species (Reese, 1968). In addition, a number of behavioral researchers in applied and educational settings have investigated relational responding as it applies to category and concept learning (e.g., Englemann, 1967; Englemann, Carnine, & Steely, 2001; Kinder & Carnine, 1991; Markle & Tiemann, 1970). However, other than Lowenkron (1989), who reported a series of experiments demonstrating stimulus control over relational matching in children, there has not been much empirical research or conceptual discussion concerned with the stimulus control of arbitrary relational responding. One place where this issue has been addressed is Relational Frame Theory (RFT, Hayes, Barnes-Holmes, & Roche, 2001).

RFT is a comprehensive account of relational responding that views stimulus equivalence as one of several types of stimulus relations. RFT also is offered as a general theory of verbal behavior, and in that regard, it is necessarily focused on arbitrary relations among stimuli. Arbitrary relations result from social-verbal contingencies rather than from the physical or formal properties of the stimuli that are related. For example, the relation between words and their referents is arbitrary in that it is established by social contingencies; words usually bear no physical resemblance to their referents. In the present experiment, the experimental contingencies established arbitrary relations between the A, B, and C stimuli and the physical relations smallest, middle, and largest, respectively. In that way, the samples were related to their respective physical relations in the same way that the words *smallest, middle, and largest* are related to the physical relations they name.

Within RFT, the term C_{rel} (context of relating) is used to refer to a context ''in which a history of a particular kind of relational responding is brought to bear on the current situation'' (Hayes et al., 2001, p. 30). A defining characteristic of such contexts is that they occasion arbitrary relational responding or establish arbitrary relations among stimuli. The sample stimuli in the present experiment partially fit the definition of C_{rel} in that they occasioned relational responding to the comparison stimuli. However, the operative relations were nonarbitrary in that they were based on the physical dimensions of the comparison stimuli. For the samples to qualify as C_{rel}, it would be necessary to show that they can be used to establish arbitrary relations among a set of stimuli. That was the purpose of Experiment 2.

EXPERIMENT 2

Method

Participants, Setting, and Apparatus

Participants were recruited, compensated, informed, and debriefed exactly as described in Experiment 1. The first 6 (4 females, 2 males) participants to volunteer and successfully complete the relational training were selected for the study. Their ages ranged from 18 to 23 years. All participants completed the experiment in a single session that lasted between 1.5 and 2 hr. Experiment 2 was run in the same setting as Experiment 1, and the same computer was used to present stimuli and record responses.

Procedure

Experiment 2 consisted of three phases. The first was the same relational training described in Experiment 1, and all of the procedures and criteria were identical.

The second phase consisted of two components: training and testing. Training was intended to establish a size ranking among a set of four colored circles. Training trials consisted of a series of two-choice arbitrary match-to-sample trials. On every training trial, A (the sample that had been related to the smallest comparisons in the relational training task) was presented as the sample in the center of the upper third of the computer screen. The comparisons were two of four differently colored circles presented equidistant from the center in the lower third of the screen. The four circles are here labeled G, P, Bl, and R and correspond to the colors green, purple, blue and red, respectively. Three examples of training trials are presented in the top half of Figure 4. Participants selected the ''correct'' colored circle by pressing the corresponding arrow key on the keyboard. Feedback for correct and incorrect selections was exactly as in the relational training task.

Before the start of the training trials, participants were given the following instructions: ''This part of the experiment is similar to the last except that you will see two colored circles at the bottom of the screen instead of three stimuli that vary in size. Just like before, your job is to select the correct colored circle given the symbol at the top of the screen. Any questions?''

The purpose of the training was to create the following arbitrary rank ordering among the four colored circles: G $<$ P $<$ Bl $<$ R. To do this, the computer was programmed so that in the presence of sample A (smallest), selections of G were always correct, regardless of the other comparison. Selections of P were correct when the other comparison was either Bl or R, and selections of Bl were correct when the other comparison was R. Selections of R were never correct. The spatial locations of the colored circles varied randomly across trials, as did the two circles that were presented as comparisons. A correction procedure was used such that specific trials were repeated until participants made a correct selection. Samples B and C were never presented. Training trials continued until participants reached a criterion of 12 consecutively correct selections.

The testing part of Phase 2, which was introduced without instructions or other indication of a change in the task, consisted of a series of three-choice match-to-sample trials presented without feedback. On these trials, A, B, and C were presented randomly but equally often as samples, and three of the four colored circles (e.g., G, P, and Bl) were quasirandomly presented as comparisons (see the bottom panel of Figure 4). Selections were scored ''correct'' depending upon the sample. If the previous relational training had established the intended relational functions for A, B, and C, and if the immediately preceding training had produced the intended rank ordering of the colored circles, then participants should

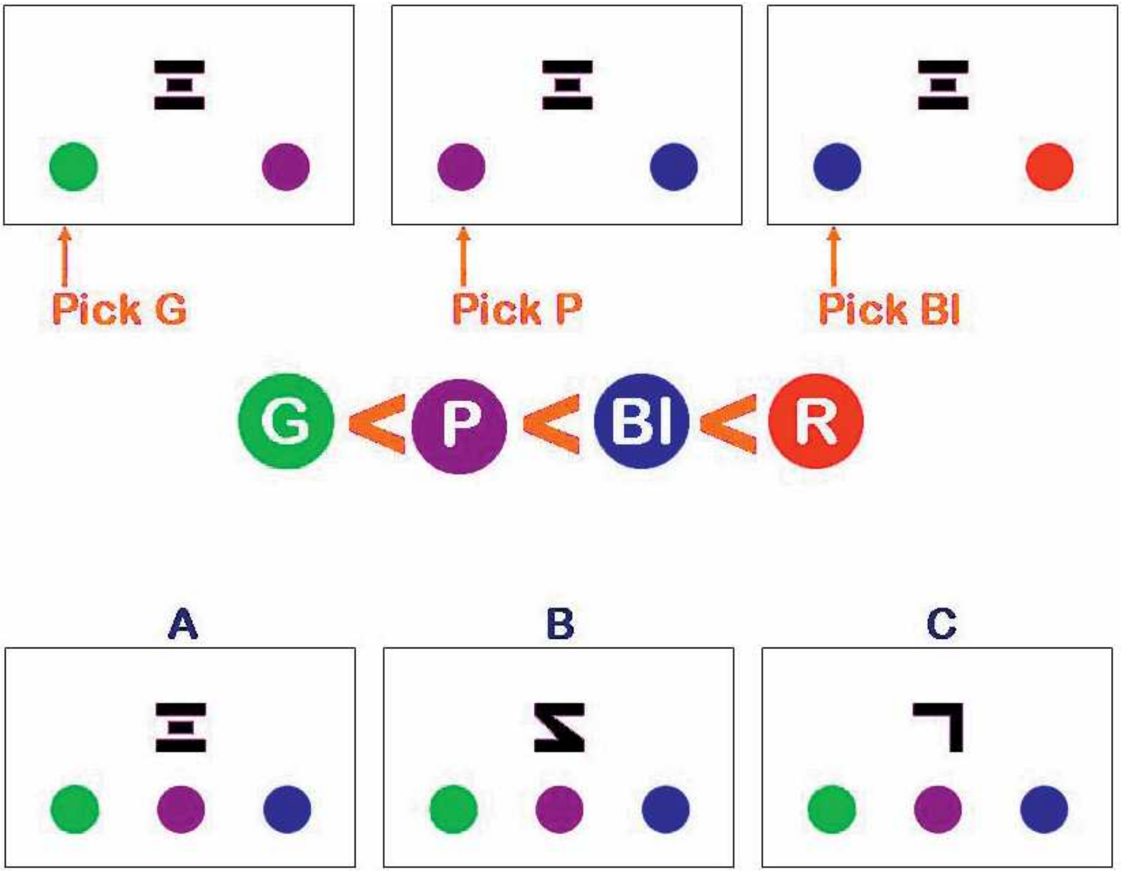

Fig. 4. Three examples of training (upper panel) and testing (lower panel) trials used in the second phase of Experiment 2.

select the ''smallest'' of the three colored circles in the presence of sample A, the ''middle'' colored circle in the presence of B, and the ''largest'' colored circle in the presence of C. Thus, given sample A, G was always considered the correct comparison. But P, the next ''smallest'' color, was considered correct if the other comparisons were Bl and R. In the presence of sample B, G and R were never correct. P was correct if the other comparisons were G and Bl or G and R, and Bl was correct if the other comparisons were P and R. In the presence of sample C, R was always correct, and Bl was correct if the other comparisons were G and P. Eighteen test trials (six per sample) were presented with the spatial location of the comparisons randomized.

The third phase of the experiment was identical to the bar press phase of Experiment 1, except that bar press responses were trained in the presence of P instead of sample B, and the G and Bl circles were used on test trials instead of the samples A and C. R was not presented during this test because participants in Experiment 1 pressed the bar in the presence of C at rates that were quite high and quickly led to fatigue. Comparable rates were observed in the presence of Bl, and we were concerned that bar press rates in the presence of R would be so high that fatigue would occur too quickly to get reliable response rates.

Results and Discussion

All 6 participants met the relational testing criterion in Phase 1 after 12 training series. All 6 also quickly reached training criterion in Phase 2 (number of trials ranged from a low of 18 to a high of 72). Participants' responses on

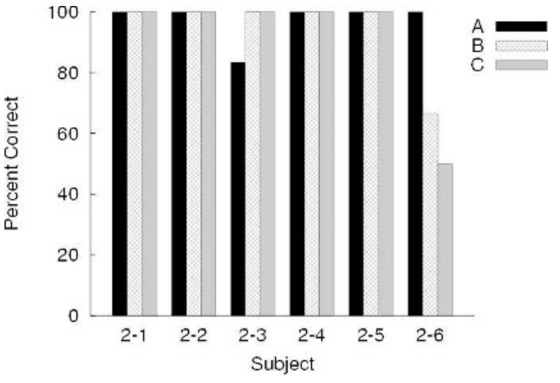

Fig. 5. Percent correct for each participant on the A, B, and C test trials in the second phase of Experiment 2.

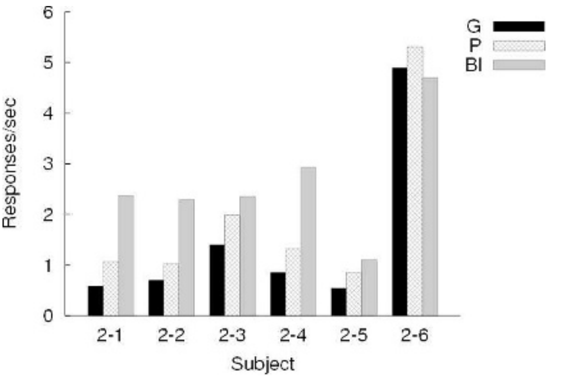

Fig. 6. Responses per second to the Purple (P), Green (G), and Blue (Bl) circles for each participant on the testing trials in Phase 3 of Experiment 2.

the testing trials of Phase 2 are presented in Figure 5. These data are presented as percent total correct on the six trials on which A, B, and C served as samples. Four of the 6 participants performed perfectly on all test trials. Participant 2-3 responded correctly on 83% (five of six) of the A sample trials and on all of the B and C sample trials. Participant 2-6 responded correctly on all of the A sample trials but on only 66% and 50% of the B and C sample trials, respectively.

Presented in Figure 6 are the bar press rates for each of the participants in Phase 3. Except for Participant 2-6, the rates at which the participants pressed the bar were in line with the rank ordering trained in the first part of Phase 2 ($G < P < Bl$). Participant 2-6, who performed relatively poorly on the B and C test trials in Phase 2, responded at a higher rate to all stimuli than any of the other participants and slightly faster to P than to G and Bl, which evoked similar response rates.

The present results again demonstrate the transformation of stimulus functions in line with trained relations in the absence of any experimentally established stimulus classes. The relational training procedures transformed the functions of A so that it could be used to establish a rank ordering among the colored circles. These relations transformed the functions of the circles so that they functioned exactly as the comparisons in Experiment 1, which varied in size. Moreover, the relational training transformed the functions of A, B, and C so that they reliably occasioned the selection of the ''smallest,'' ''middle,'' and ''largest'' ranks, respectively. Like the comparisons in Experiment 1, the colored circles combined with the samples to control participants' selections in the three-comparison match-to sample tests in Phase 2. The effects of the training in Phase 2 also were evident on the bar press task, where, for 5 of the 6 participants, the circles evoked rates of bar pressing that were directly in line with their ordering.

As stated earlier, in both Experiments 1 and 2, the functions of A, B, and C were acquired by relating them directly to nonarbitrary features of the comparison stimuli (i.e., their actual relative sizes). As a result, it is possible (although perhaps not likely) that the transformation of functions that was observed for those stimuli in both experiments were not based on derived relations among the samples, but rather on their individual associations with the nonarbitrary features of the comparison stimuli. In other words, the evoking and eliciting functions indirectly acquired by A and C in Experiment 1 may have been due to their direct associations with the smallest and largest comparisons, respectively, rather than their derived relation to B. It remains to be seen whether the relational training procedures actually established relations among the samples. That was the purpose of Experiment 3.

EXPERIMENT 3

Method

Participants, Setting, and Apparatus

Participants were recruited, compensated, informed, and debriefed exactly as described

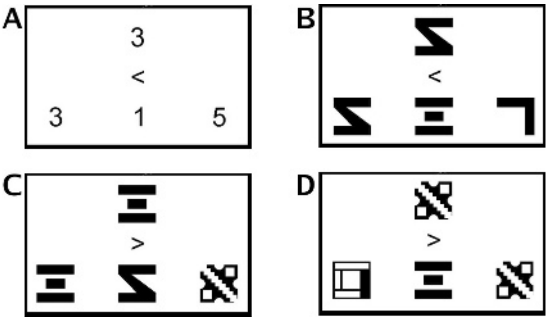

Fig. 7. Panel A: A sample training trial from Phase 2 of Experiment 3. Panel B: A sample test trial from Phase 2 of Experiment 3 with A, B, and C. Panel C: A sample test trial from Phase 2 of Experiment 3 with a novel comparison (A-). Panel D: A sample test trial from Phase 2 of Experiment 3 with A- as both sample and comparison, and A-- as a novel comparison.

in Experiment 1. The first 7 students (6 males and 1 female) to volunteer and successfully complete the relational training were selected for the study. Their ages ranged from 18 to 22 years. All participants completed the experiment in a single session that lasted between 1 and 1.5 hr. Experiment 3 was run in the same setting as the previous two experiments, and the same computer was used to present stimuli and record responses.

Procedure

There were two experimental phases. The first consisted of the same relational training task used in Experiments 1 and 2. Phase 2 consisted of two parts. In the first, participants received a series of training trials that were intended to acquaint them with the form and response requirements of the subsequent test trials. On each trial a number appeared in the middle of the top third of the computer screen, an equal or inequality sign appeared in the middle of the screen, and a series of three numbers appeared equidistant from each other across the bottom third of the screen. One of the three numbers on the bottom third of the screen was less than the number at the top, one was equal to, and the other was larger than the number at the top. An example trial is presented in the Panel A of Figure 7. To start, participants were told to read the screen as if they put the top number to the left of the sign in the middle of the screen and to select the number on the bottom that made the statement true. Participants made their selections by using the arrow keys on the keyboard. Thus, the example in Figure 7 would be read as ''3 is less than 3, 1, or 5?'' and the correct response would be the right arrow key on the keyboard. Participants received a series of similar trials until they responded correctly six consecutive times. This was a simple task and all participants performed without error.

Part 2 consisted of a number of testing trials which were introduced without instructions or other indication of change. These testing trials were similar in form to the training trials, but the numbers were replaced with either just the samples used in the relational training (A, B, C) or some combination of these samples and novel shapes (i.e., shapes that the participants had not seen previously). In addition, no feedback was provided after participants' selections. The first 18 testing trials used just the samples. A sample trial of this type is presented in Panel B of Figure 7. On this trial, B is the sample, and A, B, C are the respective comparisons. Based on the previous relational training, the ''correct'' answer here would be C.

Subsequent trials introduced novel shapes, first as comparisons and later as both samples and comparisons. Examples are presented in Panels C and D, respectively, of Figure 7. The purpose of these trials was to see whether participants would infer or extrapolate the rank ordering to the novel stimuli, based on the previous relational training and the configuration of the particular trial. For example, in the trial presented in Panel C, A is the sample and left comparison, B is the middle comparison, and a novel shape is the right comparison. Because A cannot be greater than itself and is less than B, the ''correct'' selection here, by exclusion, would be the novel (right) comparison. The right comparison, then, is less than A. We labeled this shape A-.

In the sample trial presented in Panel D, A- is the sample and the right comparison, a novel shape is the left comparison, and A is the middle comparison. Here the correct response would be the novel shape, because A- cannot be greater than itself and is less than A. Because the novel shape is ''less than'' A-, we labeled it A--. Similar trials with novel stimuli were used to establish a shape that was ''larger'' than C (C+), and one that was ''larger'' than C+ (C++).

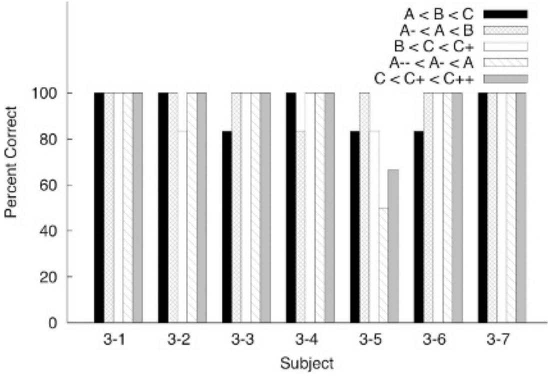

Fig. 8. Percent correct for each participant on each test trial in Phase 2 of Experiment 3.

In all, five different trial types were presented: A < B < C; A- < A < B; A-- < A- < A; B < C < C+; and C < C+ < C++, and each trial type was presented six times without feedback. Trials were configured in such a way that there was only one possible ''correct'' answer based on the previous relational training and test trials. As was the case in the previous experiments, the serial positions of the comparisons varied randomly across trials.

Results and Discussion

Again, all participants met the relational testing criterion after 12 training series. Each participant's percentage of correct responses on each type of test trial in Phase 2 is presented in Figure 8. Two participants (3-1 and 3-7) responded correctly on every test trial. Four participants (3-2, 3-3, 3-4, and 3-6) responded correctly on all but one trial type, and even on those trials, they responded correctly on five of six trials. Participants 3-3 and 3-6 made incorrect selections on the first A < B < C trial types. Participant 3-2 made incorrect selections on one of the B < C < C+ trial types, and Participant 3-4 made incorrect selections on one of the A- < A < B trials types. Participant 3-5′s selections were inconsistent. Her responses were 5/6, 6/6, and 5/6 correct on trial types A < B < C, A- < A < B, and B < C < C+, respectively. However, her performance was correct on 3/6 A– <A- < A trials and 4/6 correct on C < C+ < C++ trials.

These findings show that the relational training used in the present experiments not only can transform the functions of the stimuli used as samples in that training, but can establish a set of derived relations among them. When directly assessed, participants reported that A was less than B, and B was less than C. Moreover, these derived relations were used to derive additional relations among a set of novel shapes to produce an arbitrary size ordering of seven abstract forms.

GENERAL DISCUSSION

Taken together, the three experiments reported here demonstrate that: a) the functions of stimuli can be transformed in line with relations other than equivalence and in the absence of established stimulus classes; b) the relations established for the samples used in the relational training could be used to establish ordering relations among a set of colored circles; c) these relations modified the stimulus functions of those circles such that they occasioned different rates of bar pressing; d) the relational training procedures resulted in the emergence of entailed relations among the samples; and e) these entailed relations could be used to establish a size ranking among a group of novel shapes.

As stated previously, the purpose of Experiment 2 was to see if the relational training procedures would alter the functions of the samples so that they could be used to establish relations among a set of stimuli. In the language of RFT, the purpose of Experiment 2 was to see if the relational training would establish the samples as stimuli or contexts that occasion relational responding, or C_{rel}. At least with respect to A, which was used to establish the arbitrary size relations among the colored circles and to transform their functions accordingly, the answer appears to be yes. To our knowledge, this is the first demonstration of the establishment of C_{rel}, or stimulus control over relational responding as defined by RFT.

Another finding of the present study relevant for RFT is that multiple exemplar training was used to establish the samples as C_{rel}. This is in line with the plausible but not yet empirically validated assertion that the contextual control of relational responding is likely acquired through abstraction or multiple exemplar training (Hayes et al., 2001). Of course, multiple exemplar training has been used for many years and in many contexts to establish stimulus classes, categories, concepts, and generative responding (e.g., Baer, Peterson, & Sherman, 1967; Stokes & Baer, 1977), but the use of multiple exemplars to establish contextual control of relational responding has not yet been demonstrated. In the present experiments, many features of the comparisons varied across trials, but the relation between the samples and the relative size of the comparisons remained constant. This allowed subjects to abstract (i.e., come under the control of) the relational properties of the samples and behave appropriately when faced with novel comparison arrays. Whether abstraction is the process by which contextual control over relational responding emerges naturally is still to be determined, but multiple exemplar training was sufficient to produce C_{rel} in this experiment.

Although it seems clear in Experiment 2 that the ability of the colored circles to occasion different rates of bar pressing was due to the derived or entailed relations among the circles, it is less clear that the operant and respondent functions of the samples in Experiment 1 were due to entailed relations among A, B, and C. It is possible, although perhaps not likely, that these functions stemmed directly from their individual nonarbitrary relational functions. Thus, it is possible that A and C evoked different rates of bar pressing and elicited different skin conductance responses from B not because of their respective relations to B, but because of their individual and independent relations to the smallest and largest comparisons. A direct assessment of derived relations among the samples in Experiment 1 was not conducted prior to the transformation of functions tests. However, the results of Experiment 3 demonstrate that the relational training procedures established derived relations among the samples and add support to the view that the transformation of stimulus functions observed in Experiment 1 was based on the derived relations among A, B, and C.

To varying degrees, each of the present experiments required participants to abstract, infer, or extrapolate. In all three experiments, participants could be said to have abstracted the stimulus relations that were discriminative for reinforcement in the presence of the three samples. It could also be said in ordinary language that participants were required to infer or extrapolate a) the appropriate rates of bar pressing in Experiments 1 and 2; b) the level of shock they might receive following A and C in Experiment 1; c) the correct colored circle to select on the training and testing trials in Experiment 2; and d) the relative ''sizes'' of the novel stimuli presented on test trials in Experiment 3. The terms abstraction, inference, and extrapolation fall under the general rubric of human cognition or higher-order skills, and cognitive psychologists have studied them extensively (e.g., DeLosh, Busemeyer, & McDaniel, 1997). Behavior analysts working in applied and educational settings (e.g., Baer et al., 1967; Englemann, 1967; Englemann et al., 2001; Kinder & Carnine, 1991; Markle & Tiemann, 1970; Stokes & Baer, 1977) have examined ways of establishing these higher-order repertoires in selected populations, but these repertoires have been given relatively less attention in the basic behavior-analytic literature. One theoretical implication of the three present experiments is that they point to behavioral repertoires that may account for these cognitive processes. In particular, inference and extrapolation seem to be products of relational responding, where relational responding refers to a generalized operant class characterized by responding to one stimulus in terms of another and the emergence of entailed or derived stimulus relations (Hayes et al., 2001). Ostensibly through a history of multiple-exemplar training, most language-able humans when presented with a specific relation among a set of stimuli are able to derive and respond appropriately to the entailed relations among those stimuli. For any given relation or set of relations, there is an entailed relation or set of relations that the verbal community establishes as true and reinforces. For example, if it is given that A is less than B, then the entailed relation B is greater than A is considered true, and stating it or acting in accord with it is likely to be reinforced. Similarly, if it is given that $A < B < C$, then the entailed relations $B > A$, $C > B$, and $C > A$ are also true. Once these entailed relations are learned, they can be abstracted and applied to any set of stimuli for which a relation or set of relations holds, and this applies equally well to both nonarbitrary relations and arbitrarily imposed relations. Included in the RFT definition of relational responding is the notion of transformation of function, which states that the functions of stimuli are transformed in accordance with their relations to other stimuli. As stated earlier, this is a robust finding in the stimulus equivalence literature, and the present results along with those of Dymond and Barnes (1995) and Roche et al. (2000) suggest that it is also true of stimulus relations other than equivalence. Although there is still some confusion and controversy surrounding RFT (e.g., Malott, 2003; McIlvane, 2003; Palmer, 2004), it is not hard to imagine that humans can acquire relational repertoires of the type it describes. If so, then it is easy to see how at least some types of inference and extrapolation can be seen as examples of derived relational responding and how the functions of the stimuli involved in inferential and extrapolative processes can be transformed.

In addition to their theoretical implications, the findings of the present experiments also have clinical implications. One of the reasons given for the rise of the cognitive therapies (this includes the cognitive-behavior therapies) is that there does not appear to be a direct relation between clients' actual experiences and their clinical symptoms (e.g., Marks, 1981, 1987; Rachman, 1977). Clients with very strong fear or anxiety reactions often have little or no aversive experiences with the events and situations they fear, and quite often clients avoid events and situations in which they have never actually been punished. In response, many cognitive-oriented therapists and clinical researchers have argued that cognitive structures must mediate between actual experiences and behavior. These cognitive structures have been given various labels including beliefs, schema, and expectancies (e.g., Mineka & Tomarken, 1989; Reiss, 1980). One could apply such an account to the behavior of the participants in Experiment 1, who showed skin conductance reactions to both A and C, even though neither had ever been associated with shock. It might be said that these participants expected or believed that certain levels of shock would follow A and C. They probably did, but expecting and believing are instances of behavior, and employing them as explanations is not particularly helpful if the conditions that give rise to them and the processes by which they interact with other behaviors are not articulated. The present findings suggest that relational responding and the attendant transformation of functions may be the behavioral processes that replace these cognitive structures and explain clinically relevant behavior.

Although the present procedures appear to have eliminated the potential confounds associated with previous studies concerned with the transformation of functions via relations other than equivalence, there are two limitations of the present experiments that need to be addressed. One is the relatively explicit nature of the instructions in several phases of the experiments. For example, in the relational training phases participants were told that there always was a correct answer and that they should use what they learn on trials with feedback to respond on trials without feedback. In the bar press training phases, the instructions directed participants to press the bar at the rate they thought appropriate for each symbol presented. The fact that the control participants in Experiment 1 failed to respond to the A, B, and C stimuli as the experimental participants did, suggests that the relational training procedures were critical, but less explicit instructions would allow for a more direct assessment of the effects of the experimental contingencies alone.

The second and more general issue, however, concerns the use of participants with well-developed verbal repertoires, long histories of responding to verbal instructions, and a good deal of practice in trying to discern what is expected in novel contexts. Given that normally developed humans tend to verbalize (label, categorize, evaluate, etc.) almost continuously as they interact with their environments, it is likely that the present participants figured out early on what was expected of them and simply labeled the three sample stimuli as ''smallest,'' ''medium,'' and ''largest,'' respectively. Even if it is assumed, however, that participants did label the stimuli thus, labeling cannot serve as an adequate explanation of the present results because the labeling itself needs to be explained. Apart from direct instruction about the meaning of the samples, which likely would have yielded similar results, in order for the samples to be labeled correctly as ''smallest,'' ''medium,'' or ''largest,'' they presumably must have had at least some of the stimulus properties of other stimuli that have been similarly and correctly labeled in the participants' past. In the present experiments then, the basis for labeling the samples would have to have been their respective correlations with the correctly selected, relatively sized comparisons. Moreover, because the samples were novel stimuli, their relational properties must have been acquired via the relational training procedures. Accordingly, the very process of labeling the samples would be an instance of transformation of function via stimulus relations other than equivalence. More specifically, even if A occasioned the covert verbal response ''choose smallest,'' that function must have resulted from differential reinforcement for responding relationally.

Nonetheless, given the participants' verbal histories, no reasonable claim can be made that the relational repertoires observed in these experiments were established solely within the experiment. What can be claimed, however, and this is probably true of all equivalence and derived stimulus relations studies with verbally competent participants, is that the experiments demonstrated control over relational responding that had not yet been shown to be controlled by relational training or match-to-sample procedures.

Admittedly, the fact that verbally competent humans continuously verbalize as they interact with programmed contingencies makes it difficult experimentally to isolate the effects of their verbalizations. The obvious challenge for future research with such participants is to identify the determinants of the verbal behavior that occurs in human operant experiments and to clarify how it interacts with the behaviors that serve as dependent variables in those studies.

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